TEMPORAL ANALYSIS OF THE JAVELIN THROW

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INTRODUCTION

The goal of the javelin throw is to maximize the distance thrown without fouling. The final step of the throw's approach and its release conditions have been studied in great detail. Most authors agree that the release velocity of the javelin is the single most important factor in determining the distance thrown.

The purpose of this project was to take existing videographic records of elite male javelin throwers and analyze the records to find relationships between segments of the throw and the distance thrown. The project examined throwers both individually and as a group to see whether one common throwing style is present in all throwers, if there are two or three common throwing styles present, or if each thrower has a style unique to that individual. Throws were divided into time segments and combinations of the time segments, which were analyzed for relationships with the distance thrown and each other. Information gathered from this study should allow coaches and throwers to devote a greater proportion of training to the aspects of the throw that have the most bearing on the distance thrown.

BACKGROUND

A javelin thrower's running velocity is determined by the thrower's approach. The release velocity is agreed upon as the most important factor in determining how far a javelin is thrown. The thrower tries to maximize the release velocity by efficiently transferring the horizontal linear momentum generated in his running approach to angular momentum of the legs, hip, trunk, shoulder, elbow, and wrist at the end of the approach, and then to the momentum of the released javelin through the hand (Terauds, 1985).

The javelin throw is commonly divided into four phases: approach, transition, pull and release, and follow through. The approach consists of the first eight to twelve steps run with the javelin held in a fixed position relative to the rest of the body to develop speed and momentum. The transition is a series of crossover or shuffle steps taking place as the throwing arm is extended behind the trunk to prepare for the arm action that will accelerate the javelin with respect to the body immediately before release. This phase culminates with the final throwing side foot touchdown prior to release. Pull and release consists of the throwing arm reaching full extension, the brace foot being planted, and the arm moving forward until release. This phase serves to provide maximal velocity to the javelin, though direction and orientation are also critical. The follow through is needed to decelerate the body before it crosses the foul line, and to reduce the chance of injury.

Ikegami et al. (1981), Miller and Munro (1983), Komi and Mero (1985), Rich et al. (1985), Whiting, Gregor, and Halushka (1991), and Mero et al. (1994) have performed biomechanical analyses of the javelin throw. The general consensus was that release velocity was the single most important factor in determining the distance thrown. Most of these studies did not examine the temporal relationships between events in the javelin throw, although Ikegami et al. (1981), Miller and Munro (1983), Komi and Mero (1985), Whiting, Gregor, and Halushka (1991), and Mero et al. (1994) did measure the time interval from double foot (brace foot) plant until release.

METHODS

Videographic records of elite male throwers at various international events over the 1992-1993 seasons, as well as the 1992 Olympics and 1993 and 1995 World Championships, were examined. Top U.S. male throwers from the 1988 and 1992 U.S. Olympic Trials, and the 1993 and 1994 Olympic Festivals, were also analyzed. Eleven performers, each with three or more useable throws, were analyzed as part of the group. The eleven performers were subdivided into two categories: those with more than ten useable throws (major throwers), and those with fewer than ten useable throws (minor throwers). The major throwers were analyzed individually, then were grouped with the other major throwers (major group), and finally as part of all eleven grouped together, while the minor throwers were only included in the overall group analysis. A total of ninety-five throws were analyzed, with seventy-threeof those coming from the five major throwers.

The analysis consisted of temporally digitizing the raw videographic records using frame advance. The distances thrown (DIST) were recorded in meters and the times were recorded in seconds. Touchdown was defined as the first frame in which contact with the ground could be seen. Release was defined as the first frame in which the javelin had separated from the hand.

Each thrower's running phase was divided into five time segments. The first segment was the approach time segment (APP). The duration of APP is greatly influenced by the distance covered, which will vary, but is relatively constant for each thrower. Its beginning was defined as first forward motion, and its ending was defined as the first touchdown of the throwing side foot after withdrawal of the javelin begins. Withdrawal is the extension of the throwing arm behind the body into the throwing position.

The second segment was the withdrawal time segment (WDL) itself, which lasted from the end of APP to the first touchdown of the opposite (non-throwing) foot after withdrawal ended with the throwing arm completely extended. Following this was the penultimate step time segment (PNU), which began with the end of WDL and ended with the next touchdown of the throwing side foot. The penultimate (next-to-last) step time segment was where the so-called "crossover step" occurred. The preparatory step time segment (PRP) began at the end of PNU and ended with the touchdown of the brace (opposite or non-throwing) foot. This ending point has also been called double foot plant or double support. This was followed by the final time segment, the release time segment (REL), beginning with end of PRP and ending when the javelin was released.

Three additional time durations were defined as combinations of the above time segments. Two of these divide the analyzed portion of the javelin throw into two halves. The dividing point was chosen because that point, the touchdown of the lead (non-throwing) foot at the end of withdrawal, separates the thrower's normal running rhythm, where the steps are of relatively equal length, from steps of unequal lengths (Terauds, 1985): The first of these, the before lead foot touchdown time combination (BLF), was defined as the sum of APP and WDL. The second time combination, after lead foot touchdown time combination (ALF), was equal to the sum of PNU, PRP, and REL. The third was the total time combination (TOT), the sum of all five time segments.

Once the videographic records were digitized, they were entered into several Microsoft Excel spreadsheets. Statistical analysis was performed on each major thrower and each group. Correlation and regression analyses for the eight variables (five segments and three combinations) versus distance were performed within Microsoft Excel.

RESULTS

CORRELATION ANALYSIS

Correlation analysis was performed on the digitized data from each of the individual five major throwers and each of the groups to determine the presence of any relationships that would be useful in identifying stylistic patterns associated with success. Furthermore, correlation analysis was performed on the data averaged for each of the eleven individual throwers, as well as the data averaged for the five major throwers.

Table 1. Summary of Significant Relationships ($p<0.05$)

Thrower	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MB							+		+	+	+		+		+			+	+	+	+			+		+		+
BC									+	+	-		+							+				+				+
EK									+	+	+									+								+
TP				-			-		+	+									-	+	-					+	-	+
JZ								-	+	+							-			+			-		-			+
AG		-	-	+	-	+			+	+				+		+	+	+		+		+		+		+		+
MG	-	-	-	-	-	+			+	+	+	+	+	+	+	+	+	+		+		+		+		+		+
AA				-					+	+				+		+				+				+		+		+
MA				-					+							+								+				

Note: (+): significant positive correlation; (-): significant negative correlation; AG: all throwers grouped together; MG: major throwers grouped together; AA: averages of each of the throwers; MA: averages of each of the major throwers.

Four significant relationships (APP/BLF, APPITOT, PNU/ALF, BLFI TOT) were present in all of the individual throwers analysis, the entire group and major group analysis, and the averaged entire group. These findings were expected because all involve time segments, i.e., APP, that make up a majority of a time combination, i.e., TOT.

REGRESSION ANALYSIS

Regression analysis was performed on the data from each of the five individual throwers and group of all throwers to try to find a predictive equation for distance thrown using the five time segments. However, this analysis did not produce any meaningful results for any of the individual throwers, most likely due to the small size of the data sets.

Based on the results of a multiple regression analysis, a manual backward step regression analysis was performed, whereby the least important independent variable is removed as a variable and the regression analysis is then run on the remaining variables. A predictive equation that accounted for 59.8% of the variation in the distance thrown was developed from the backward step regression. The predictive equation is:

$$DIST = 105.757 - 241.865(REL) + 1.349(APP) - 4.129(WDL).$$

DISCUSSION

DISTANCE THROWN

Previous biomechanical studies of javelin throwing focused on the pull and release phase, defined here as PRP and REL. The times found in these studies were similar to those found here. The average PRP and REL times for all the analyzed throws in this study were 0.215 s and 0.121 s, respectively. Whiting, Gregor, & Halushka (1991) and Mero et al. (1994) found values of 0.224 s and 0.221 s, respectively, for PRP. The REL times found previously are 0.13 s (Ikegami et al., 1981), 0.12 s (Komi & Mero, 1985), 0.14 s (Rich et al., 1985), 0.115 s (Whiting, Gregor, & Halushka, 1991) and 0.135 s (Mero et al., 1994). The assumption made by focusing on the pull and release phase is that the release velocity is generated in this phase. All the attention on the pull and release phase at first appears to be supported by the findings for the groups here that DIST/PRP and DIST/REL have a negative correlation. This means that faster PRP and REL times are correlated with longer throws. In addition, for both groups there were positive correlations for REL/PRP and REL/PNU, while the major group also had a positive correlation for WDL/REL. These results suggest the speed generated in earlier segments of the running phase may be carried over to the REL segment, which results in a longer throw the shorter the REL time.

Only one individual thrower showed any correlation with DIST. Thrower TP had the same negative correlation as the groups for DIST/REL. He did not, however, show the same apparent carry over of speed into REL as the groups.

INDIVIDUAL STYLES OR UNIVERSAL TECHNIQUE

Comparisons between the results of the correlation analysis for the grouped throwers and the individuals' averages were made to determine whether a universal pattern predicts the distance thrown independent of the thrower or whether each thrower has developed their own style. Since data from the average groups were essentially similar to their respective group data, the throws appeared to sort themselves by individual style.

Thrower MB appeared to carry over much of his speed between segments. There were positive correlations present for APP/PNU, WDL/PNU, WDL/REL, and PNU/REL, indicating that throws with one fast time segment tended to have fast values for all segments. In addition, there were two positive correlations between segments and time combinations not composed of those segments. These two relationships were WDWALF, and PNU/BLF. This reinforces the idea that this thrower maintains speed throughout the throw.

PREDICTIVE EQUATION

The predictive equation determined from the regression analysis can only be used with a number of different throwers at a time, because it will only be accurate for a group of throwers, This equation cannot accurately be used to predict throws for an individual thrower. Individual predictive equations could be determined in a similar fashion if the number of analyzed throws is large enough to yield significant results from the regression analysis. The predictive equation showed that REL is the most important time segment that can be used to predict the distance thrown. This was expected, since this final time segment has the greatest effect on the release conditions, which, along with wind velocity and gravity, determine the flight characteristicsof the javelin. Coupled with the negative correlations between REL and DIST found for both groups, this presented strong quantitative evidence of an important inverse relationship between REL and the DIST.

APP ranked second to REL in the predictive equation. This result must be viewed with caution, as this time segment depends on the distance ran, which varies. Since no significant relationshipfor APP/DIST was found in the correlation analysis, APP may only be helpful in predicting distance thrown when used in conjunction with REL and WDL. Ranking third in the predictive equation, WDL also appears to be complementary to REL and APP in predicting distance thrown. However, since corroborating evidence from the correlation analysis is inconclusive, WDL alone could not be used to predict DIST.

CONCLUSIONS

The results of this study show that a shorter release time segment was the most important factor in producing a greater distance thrown. They also suggest that speed generated early in the running phase may be carried over or maintained in later segments. Thus, a major suggestion for improving javelin throwing performance would be to increase the running speed and the extent to which this speed is maintained during the throw. For this sort of analysis, a minimum of fifteen throws would be necessary to perform an accurate correlation analysis for individual.

Different individual styles also appeared to be present, rather than two or three universal styles. In addition, to determine a significant predictive equation for an individual's distance thrown, a larger number of throws needs to be examined. Based upon a previous analysis not incorporated in this study, a minimum of forty throws from an individual thrower is suggested for regression analysis.

Once correlation and regression analyses have been performed on an individual thrower's initial set of videographically recorded throws, the results should be examined to find the most important time segments for the thrower. The thrower can target specific time segments, and adjust training to modify them as indicated by the analyses. Over a period of time, records should be maintained, with new analyses performed periodically to compensate for progress of the thrower. If indicated, further adjustments can be made.

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